Applying a Writing-to-Learn Strategy in a Traditional Material Science and Engineering Course

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Abstract

A traditional Material Science and Engineering course at Ohio University has been modified to use a Writing-to-Learn approach, with the primary focus on demonstrating qualitative understanding of the relationship between the microstructure and the properties of materials. The format for the qualitative portion of the course centers around daily reading and writing assignments that occur outside of class and before the material is covered in class. Classroom time is devoted to some combination of lecture, student presentations, general discussion between the students and instructor, peer review, critiques of sample responses from previous years, and practice quizzes. Writing assignments are checked immediately before or during class; but the evaluation of homework is limited to whether or not a good faith effort was made. The instructors do not provide a "correct" answer. Instead, they moderate and guide class discussions and provide their own critique of the answers as needed. Closed-book exam questions are chosen from the homework questions so students know ahead of time what material will be tested on the exams. All of the homework/exam questions are discussed in the textbook. This reduces the amount of lecture needed and makes it possible to use class time to help deepen the student's understanding of the material. A quantitative component of the course remains in place. Quantitative material is tested through traditional, open-book exams.

Introduction

A traditional Material Science and Engineering course at Ohio University has been converted to a writing-intensive course through the use of "Writing-to-Learn" activities. While the course retains a quantitative/calculation component, the emphasis is on qualitative/conceptual understanding of the course material. The focus of the course is the relationship between the microstructure and the properties of engineering materials.

While there is no dispute about the importance of written communication skills to engineers, the use of writing as a learning tool in an engineering curriculum is not common. The use of writing as a learning tool makes sense because writing skills are closely related to critical thinking skills that are essential if students are to synthesize, analyze and correctly apply course material. Furthermore, writing is an active process and, as such, is an efficicient pedagogy. As stated by Syrene Forsman, 'Writing is one the most effective ways to develop thinking[1].'

Writing Across the Curriculum (WAC) as a formal program began spreading in the 1980's.

WAC courses generally apply one or both of the ideas of "Writing-to-Learn" or "Writing in the Discipline.[2]" While Writing-to-Learn has a meaning that differs from person to person in the specifics, it universally means the students are required to record written responses to organize their thoughts and/or demonstrate their understanding of the material. Despite this twenty-year period there has been little application of writing-to-learn principles in traditional engineering courses. Most core engineering courses have a quantitative focus. Writing activities have generally been limited to the more formal assignments such as lab reports or design project reports. When qualitative questions are included in exams or homework assignments they are typically at the lower levels of Bloom's taxonomy.

Course Background

The course being discussed here is taught by chemical engineering faculty using a traditional textbook, Materials Science and Engineering, An Introduction, by W.D. Callister. The prerequisite is two quarters of general chemistry. The course is offered every quarter and rotates between three instructors. This course is required for the Chemical, Civil, Industrial and Systems, and Mechanical Engineering majors, and is an elective for those in Electrical Engineering. It averages around 40 students per quarter, and the enrollment includes students from freshman to seniors. Chemical engineering majors typically take the course in their second year, while the civil or industrial engineering majors typically take the course in their senior year. Mechanical engineering majors might take the course anytime in their curriculum. This creates a wide variety of experience, interest, and background in the students. Some have not have yet had physics. Others have had physics, statics, and dynamics, but have a four-year time delay between general chemistry and this course.

Course Evolution

The pedagogy that is currently employed in this course has evolved over many years. Beginning in 1997, one of the authors (Sampson) began to move away from using short answer, multiple choice, and fill-in-the-blank questions to evaluate mastery of course concepts and towards the use of questions designed to elicit paragraph-length answers. Within a year he had developed a list of approximately seventy such questions that were distributed to each student at the beginning of the quarter, and used to motivate daily lectures. Exam questions were selected from the same list, with some minor variations in wording intended to thwart students who attempt to memorize answers without understanding the meaning of the question.

Questions range from simple descriptions to explanations of important concepts. Some examples of questions are:

- Explain why some covalently-bonded molecules have low boiling points, while others have high boiling points.
- Compare the BCC, FCC, and HCP crystal structures.
- Describe the difference between kinetics and thermodynamics and explain the diffusion process in these terms.
- Explain the significance of a decrease in engineering stress as strain increases.
- Explain why alloy steels can be used to make larger martensite parts than plain-carbon steel.
- Describe the concept of the glass transition.

The close correspondence between lecture and exam soon led to a reduction in amount of lecture material. Neither the students nor the instructor could see the use in spending a lot of time talking about material that wasn't going to be on the exam.

Perhaps the most important departure from common practice in engineering education came when the instructor decided to eliminate material not covered in the textbook and insist that the students read the relevant textbook passages before the corresponding class period. This led, almost by accident, to the current writing-to-learn approach that is used by all of the current instructors. The best way to force students to read the textbook is to ask them to answer questions based on that reading. If the material has not been previously discussed during a lecture, the students have no alternative other than opening their textbooks.

Once the students start coming to class having advance reading and writing preparation, the need to provide a comprehensive lecture is reduced. In place of lectures, classroom time can be used for additional active-learning strategies including student presentations, peer-review exercises, critiques of answers from previous years, and practice quizzes. In some topic areas, e.g. the dreaded two-component phase diagram, a significant amount of lecture is still needed. Average students don't "get it" no matter how many times they read the text passage. However, the combined effects of eliminating extraneous content and forcing students to arrive prepared can lead to a large reduction in the amount of class time devoted to lecture.

Based upon evidence of improved student performance, Ridgway and Young began to adopt the writing-to-learn approach starting in 2000. At that point in time we learned a valuable lesson concerning implementation of active-learning strategies. One size does not fit all. While Sampson was used to having a daily schedule mapped out ahead for the entire quarter, Ridgway felt a need to adapt his delivery on the fly according to the needs of a particular group of students. While Sampson knew ahead of time where students would have difficulty, Young needed to see student work on a daily basis in order to provide better feedback to them.

Course Variations

At this point the story gets a little muddled. There is no single version of this class that is the "best" and is to be used as a strict model. In place of this, a general dedication to the use of active learning and particularly writing-to-learn serves as a foundation for an effective course where the particulars vary from instructor to instructor. The following paragraphs describe some of the possibilities.

Beginning in 2002, Sampson decided to encourage class participation by awarding credit for speaking. A graduate assistant sits in class and makes a record of every time a student says anything more meaningful than "I don't get it." What amounts to a tiny grade incentive, at most a one percent swing in the final grade, is enough to lure students into participating. The record so far is 615 recorded comments and questions during a quarter. While a few students abuse the process in a minor way, the most important effect is that the weakest students are encouraged to openly share their confusion.

Ridgway first adopted Writing-to-Learn concepts in 2000, and has essentially retained the same format to the present. Sampson's question list was used with only minor modifications. Writing exercises during the final 15-20 minutes of a 50-minute class period are used almost daily, where a question covered in that lecture is answered. These are graded using the same rubric as the exams one half to two thirds of the time, and sometimes are just graded on the good-faith-effort standard. Whether they are grading using the exam rubric is not pre-announced. Feedback provided by these answers is used to identify problem areas, which need to be corrected or clarified. Answers to questions are not required before the material is covered in lecture, primarily due to teaching style, as Ridgway prefers to adapt the material for any class period at the last minute. Modifications over the last few years have been minor. The use of answers from previous years, both good and bad, has been introduced. The students either individually or in small groups are asked to critique the response. Also the material is broken up at more regular intervals by the working of quantitative example problems from earlier material. Ridgway intends to introduce the use of pre-answers on a limited basis this coming Spring. The answers will be accepted by email

Young adopted the Writing-to-Learn strategy in her first quarter teaching the course (Fall 2004), aided by the question list that was already prepared. One difficulty for first-time instructors in a course is identifying which concepts give students the most trouble. Young felt that if she could view the students' responses to the questions in advance of class, she could identify common misconceptions or weaknesses in their answers. Young posed the questions for each class as a "Quiz" to be submitted via Blackboard, an online course-management program. Students were to complete the "Quiz" at least 1 hour prior to class, and then Young and a teaching assistant read through the answers and graded them 0, 1, or 2. Although this worked well for timely feedback to the professor, the logistics using Blackboard version 5.0 were occasionally frustrating. For example, there was no simple mechanism to provide feedback to individual students, and the only options for conducting a "quiz" were a single access by each student (not appropriate for a learning activity) or an infinite number of accesses for the duration of the course (which left no record of when the currently entered answer was actually submitted). These difficulties may be mitigated by new features in Blackboard 6.0, or by asking students to submit their answers via e-mail.

<u>Grading Rubrics</u>

Engineering educators commonly underemphasize writing in part because they are uncomfortable evaluating it. The authors have found that use of detailed grading rubrics gives the instructor confidence in her or his evaluation and helps communicate the results to the students. Again, we have discovered that allowing variation between instructors makes the tool both easier to use and more effective. Two sample grading rubrics are shown here. The first is designed primarily to guide the credit breakdown. The second is designed to emphasize the connection between critical thinking and writing skills.

Version 1

1) (4 pts) All of the main technical elements (usually two to four items) of the required answer are identified. Usually all or part of these are given in the question.

2) (5 pts) The technical elements which are present are correctly described along with their causal or sequential relationships to each other. The answer suggests that the student has a solid understanding of the material.
3) (2 pts) Appropriate scientific or engineering terminology is used throughout. Pronouns are not used unless the noun they reference is clear. Colloquial or slang terms or phrases are not present.
4) (2 pts) All of the text is grammatically correct and appears as sentences. One or two minor errors such as missing articles or incorrect capitalization are acceptable. Spelling doesn't count.
5) (2 pts) All of the information present is either a part of an introduction to the answer or the answer to the question itself. Extraneous information, which does not address the question, is not present. Information is not repeated unnecessarily or presented in an illogical sequence.

Version 2

Clarity enhancement

- A) Further elaboration is present. The idea is stated two ways.
- B) An example is given.
- C) An analogy is given.
- D) The series of elements (clauses or sentences) is written in a parallel structure.
- E) Key terms or phrases are repeated.
- F) Conjunctions (therefore, however, on the other hand, etc.) are used to show logic.
- G) Short sentences are used.
- H) The specific item and general class it belongs to are clearly defined.

Clarity detraction

- I) It is not clear what the pronoun refers too.
- J) It is not clear what the modifying clause modifies
- K) The meaning of this statement is not clear.
- L) The meaning of this statement is obscured by a serious grammatical error.
- M) The sequence of statements is not logical.
- N) The paragraph needs to be organized into two or more paragraphs.

Accuracy

- P) The statement is incorrect.

Precision

- Q) The terminology is not precise enough, not technical, or used in the wrong way.
- R) More distinguishing details are needed to illustrate the comparison.
- S) A comparative adjective (hotter, harder, faster) appears with a single noun.
- T) Numerical values or comparative adjectives are needed.

Relevance

- U) This statement is not needed or does not relate to the question.

Depth

- V) The required property or behavior is not included in the answer.

Logic

- W) The causal connection between two things is wrong.

X) An ingredient in an effect is identified as the cause of the effect.
Y) The causal connection between two things is not included in the answer.

Writing

Z) The statement has a grammatical error that detracts from readability.
AA) This statement or word is too informal for technical writing.
BB) Human qualities have been attributed to inanimate objects (anthropomorphized).

Assessment

There have been no controlled studies to verify the effectiveness of the techniques described in this paper. The authors are convinced that improvement has occurred as the course has evolved; but none are willing to subject an entire class of students to the old style for the sake of science. One piece of hard evidence does exist. All Civil Engineering majors at Ohio University are required to take both this course and the FE Exam. The performance of the Civil Engineering majors on the Material Science portion of the FE Exam has noticeably improved relative to the national average since the format change was introduced. For the eight years preceding the change, the Ohio University Civil Engineering majors scored an average of 3% above the national average, but with a standard deviation of 5%, indicating no significant difference in performance between our students and the national average. For the four years after the change Ohio University Civil Engineering students scored an average of 9% above the national average, with a standard deviation of 2%, indicating that our students now significantly out-perform the national average on the Materials Science portion of the FE Exam.

Writing-to-learn can have additional positive effects. Even though the initial goal is to increase learning of the course material, it can also help students mature as effective communicators. This of course is an EC2000 outcome. In fact this course will meet the classification of a writing-enhanced course under Ohio University's new general education program, and would most likely meet some writing-across-the-curriculum criteria on many campuses.

There has been no statistically significant change in the average grade given in the class or in the course ratings made by the students. This may be significant in that the qualitative questions as asked now require a deeper understanding of the material than the short answer/multiple choice/list format used previously. The students are performing adequately even as the expectations of their performance are increasing.

While the writing-to-learn format allows for a great deal of flexibility in the delivery and evaluation, the content is uniform. The question list is almost identical over the various quarters, and the grading rubrics used are fundamentally the same. One of the reasons the authors thought this paper was worth presenting is that they feel strongly about the positive aspects of this writing-to-learn approach and the general framework provides ample flexibility to match the style of the professor.

Bibliographic Information
1 “A Fuller Definition of Learning.” http://wac.coloradostate.edu/intro/pop4a.cfm
2 “Writing Across the Curriculum and Writing in the Discipline.” http://owl.english.purdue.edu/handouts/WAC

Biographical Information
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